GEOLOGY OF A PORTION OF THE MARTIAN HIGHLANDS: MTMS -20002, -20007, -25002 AND -25007. C. M. Fortezzo[1] and K. K. Williams[2], [1]United States Geological Survey, Astrogeology Science Center, Flagstaff, AZ, 86001, cfortezzo@usgs.gov; [2]Department of Earth Sciences, Buffalo State College, Buffalo, NY 14222.

Introduction. As part of a continuing study to understand the relationship between valleys and highland resurfacing through geologic mapping, we are continuing to map seven MTM quads in portions of the Margaritifer, Arabia, and Noachis Terrae. Results from this mapping will also help constrain the role and extent of past water in the region. The MTMs are grouped in two different areas: a 4-quadrangle area (-20002, -20007, -25002, -25007) and an L-shaped area (-15017, -20017, -20022) within the region [1-5]. This abstract focuses on the geologic units and history from mapping in the 4-quadrangle area, but includes a brief update on the L-shaped map area.

Geologic Units. The geologic/geomorphic units of the study area are divided into the megaregolith, basin, and crater-related units (not discussed here; see [6]).

Megaregolith unit 1 (Nm_1, N(16) = 86 ± 22): Forms broad plains that contain fluvial landforms. This unit is exposed in the scarp walls of the valleys and valley networks. Interpretation: megaregolith emplaced primarily through impact processes and intercalated to various degrees with volcanic rocks and sediments and possibly localized fluvial sediments or colluvium.

Megaregolith unit 2 (HNm_2, N(16): 81 ± 22): Forms relatively smooth and areally-expansive surfaces that contain north-south-trending narrow ridges or scarps, typically ~100 m in relief. Interpretation: megaregolith emplaced by similar processes as the Nm_1, though it is younger based on stratigraphic relationships and exposures in the walls of exposed valleys and craters. The ridges are crosscut by valleys in some locations and in other locations ridges crosscut the valleys, suggesting coeval and/or long-term contribution to unit development as a secondary characteristic. The ridges are likely tectonic (wrinkle) ridges formed by lateral shortening.

Basin unit 1 (Nb_1, N(16): 55 ± 32): This unit consists of angular plates typically <100 m^2 often separated by meter-scale fractures that are filled with low albedo material. Interpretation: brecciated basement rocks related to the formation of impact basins; may represent the original crater floor.

Basin unit 2 (Nb_2, N(2): 864 ± 611): This unit forms scarp-bounded blocks and islands of materials with hummocky surfaces. Within the islands, small linear to curvilinear ridges, similar to those that form the scarp margins of the islands, protrude out of the surrounding material. Interpretation: exhumed/preserved crater floor deposits possibly a mélange of breccia from the original impacts combined with ejecta materials from Newcomb crater. The boundary scarps and the internal ridges are volcanic or sedimentary dikes formed by materials filling fractures. An alternative hypothesis, which cannot be confirmed through current spectral mineralogy, is a hydrothermal origin.

Basin unit 3 (HNb_3, N(16): 87 ± 33): Forms large fans at the mouths of the valleys of the southeast, east, and northwest portions of Noachis basin. In addition, this material forms smooth surfaces in smaller basins located southwest, northeast and northwest of Noachis basin. Interpretation: sediment emplaced as valley networks debouched. In the eastern portion of Noachis basin, the unit likely includes some Newcomb crater ejecta material at its base.

Basin unit 4 (ANb_4, Present on the floors c_1, c_2, and c_3 craters): Forms the smooth floors of craters through non-fluvial processes. This unit has higher DN values (low thermal inertia) in THEMIS nighttime IR. In some locations, ridges are present at the margins of the floor, near the mass wasting deposits of the crater walls. Interpretation: volcanic or hydrothermal resurfacing material of the crater floors.

Geologic History. *Pre- Noachian and Noachian Period (>~3.7-3.5 Ga):* The ancient crust of Mars formed in the pre-Noachian. During the Early Noachian, late heavy bombardment continued to emplace large amounts of ejecta material, and volcanic processes, likely airfall deposition given the distance of the map area from volcanic constructs, forming the unit Nm_1.

During the Middle to early Late Noachian, Paraná basin formed, west of the map area. This was followed by the formation of Noachis basin as a multiple-ring impact basin and unit Nb_1 formed as the floor of the impact basin. Newcomb crater formed with a floor similar to that of Noachis basin (Nb_1). Newcomb ejecta deposits were emplaced on the floor of Noachis basin. The eastern flank of Noachis basin was overprinted by the rim of Newcomb crater, coinciding with the weakening or partial removal of the southeastern Noachis basin rim material. These three large impacts added to the thickness of the Nm_1 and the preserved HNm_2.

During the Late Noachian, contractional (wrinkle) ridges began forming in the HNm_2 and Nb_1 units, and impact rates began to decrease. Unit Nb_2 was likely emplaced as volcanic and impact airfall materials. Volcanic upwelling, sediment infilling, and/or hydrothermal mineralization in Noachis basin filled in fractures in unit Nb_1. The fractures served as conduits for the material that formed the more resistant dikes in unit Nb_2.

Valleys began to form and to incise the loose megaregolith materials. The HNb_3 deposits began forming in Noachis basin as valleys transported material from the western flank of Newcomb crater and the plateau surface of Noachis Terra. The weakened or possible already breached southeastern rim of Noachis basin became the main conduit for water and sediment transported from the highlands into Noachis basin. The western and northern flanks of Newcomb crater were heavily dissected during this time which stripped the ejecta material from the area and formed a large scarp where the rims of Noachis basin and Newcomb crater would have overlapped. Paraná Valles formed during this time and began to erode headward toward the north-south-trending rise that was likely formed by a combination of the impacts that formed Noachis and Paraná basins. On the eastern flank of the rise, several small valleys began to incise the megaregolith and transport water and sediment through a series of small basins before finally debouching into Noachis basin.

Water began to pond in Noachis basin and likely in the smaller crater basins during this time. Because of the proximity of the remnant fans to the crater rims, the transported sediment settled out near the mouths of the valleys, beginning to form fan morphologies on the basin floor. It is likely that the U-shaped basin to the northwest of Noachis basin was beginning to undergo a degree of erosion due to groundwater. The groundwater was likely being transmitted from Noachis basin down the regional slope using the radial and circumferential fractures of the impact that formed Noachis basin. During the Late Noachian, at least the western portion of Noachis basin was filled with standing water, evidenced by the paucity of linking valleys between the eastern and southern portions of Noachis basin and its single outlet on the northwestern flank. A ~35 km diameter crater formed in northwest Noachis basin. This crater breached the rim of Noachis basin and filled with water and eventually spilled over into the U-shaped basin to the northwest of Noachis basin. This spillover likely triggered a flood event(s) that removed a large amount of the Nm_2 and HNm_2 units from the northwest portion of the map area. The smaller basins to the southwest, northwest, and northeast of Noachis basin also began amassing fluvially-transported sediment.

Hesperian Period (~3.7-3.5 Ga – ~3.3-2.9 Ga): The emplacement of the HNb_3 and ANb_4 units continued into the Early Hesperian. Fluvial dissection and headward erosion continued into the Hesperian as deposition into the basins peaked. Cratering during the Hesperian might have interrupted fluvial systems or buried those that were already extinct. In some areas, groundwater may have kept some systems active in the northern portions of the map area.

During the Late Hesperian, widespread fluvial activity ceased and Noachis basin emptied. The lack of water did not allow the valleys to react to the change in base level, leaving stranded valleys along the scarp to the west of Newcomb crater. Gullied interior walls of some of the c_2 unit craters indicate that surficial water activity may have continued into the Late Hesperian. Eolian and small impact processes began to overprint the surface geomorphology.

Amazonian Period (~3.3-2.9 Ga – Present): Eolian and impact processes became the dominant processes on the surface. Basin units began to erode with the material of the HNb_3 unit being differentially stripped from the interior of Noachis basin. The fan deposits of the HNb_3 unit were stripped of upper surface materials exposing the well-cemented and preserved negative relief portions of the valley floors. Eolian materials were organized into thin sheet-like mantles over most of the map area. Eolian ripples and small dune forms formed in some craters and transverse eolian ripples formed in some valley bottoms. Regionally, eolian materials, which typically have a very low thermal inertia, usually occur in the valleys that trend east-west. The valleys oriented more north-south are typically free of eolian ripples, although sediment does accumulate. The preferential orientation of valleys trending east-west may indicate the prevailing wind direction during, at least, the Late Amazonian.

Update of L-shaped map area. Mapping in three quads near Jones crater (MTMs -15017, -20017, and -20022) continues, and is addressing the timing of fluvial erosion and deposition in this area. Samara and Himera Valles meet southwest of Jones and continue to flow northward to the confluence with Loire Valles flowing from the southeast. These fluvial systems then emptied into Margaritifer basin. Mapping in MTM -20022 shows extensive fluvial erosion outside of Samara and Himera Valles that appears to predate the last fluvial activity in Himera Valles. In addition to erosion, at least three resurfacing deposits have been mapped in that quad. To the east and northeast, the relationship between Loire Valles and the surrounding units is being studied. At least one of the resurfacing units embays portions of Loire, helping to determine the relative timing of fluvial activity in the three main valles in this area.

References. [1] Grant, J.A. & D.A. Clark (2002) Planet. Map. Mtg. (abst.) [2] Williams, K.K. and J.A. Grant (2003) Planet. Map. Mtg. (abst.) [3] Fortezzo, C.M. and J.A. Grant (2004) Planet. Map. Mtg. (abst.) [4] Grant, J.A., et al., (2005) Planet. Map. Mtg. (abst.) [5] Grant, J.A. et al., (2009), USGS Map. [6] Fortezzo, C. M., (2009) Masters Thesis, Northern Arizona Univ.